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Concentrations of cadmium, lead and zinc in livestock feed and organs around a metal production centre in eastern Kazakhstan

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Abstract

This paper presents results of analysis of animal feed and meat (cattle, horse and sheep) products from a metal processing region (Oskemen) in east Kazakhstan. Samples were collected from a range of districts of differing distances from the main source of anthropogenic pollution and with differing underlying metal-containing geologies. Analyses for cadmium, lead and zinc revealed high concentrations in many feed and meat samples. Horse (an important food animal) samples had higher levels of contamination than cattle, which were higher than sheep. For example, mean cadmium concentrations in horse kidneys in one district were found to be 128 mg/kg and lead concentrations for liver 2.2 mg/kg. These, and other, results are generally higher than reported in many other studies in contaminated regions of eastern Europe and they can exceed State Maximal Allowed Concentrations by many times. As such levels of contamination pose a significant potential risk to human health, these results have formed the basis for subsequent research on levels of metal contamination in human tissues from affected populations. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Meat; Vegetation; Cadmium; Lead; Zinc; Kazakhstan

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1. Introduction

Kazakhstan was a leading republic producing non-ferrous metals in the former Soviet Union, most of that industry being concentrated in the east Kazakhstan region. This region contains extensive mineral resources: there are polymetallic ores, combustible slates and deposits of rare and precious metals. The length of the polymetallic belt is approximately 500 km and its width is 60]100 km. It is characterized by large quantities of ores containing copper, lead, zinc, and iron, with attendant gold, silver and a small quantity of platinoids. There are also widely distributed associated minor ores such as cobalt, cadmium, antimony, arsenic and mercury. At the present time in the polymetallic belt there are over a thousand identi®ed ore deposits divided into 10 ore districts.

Since prehistoric times this area has attracted the attention of people for its metal resources. As far back as the ®rst half of second millennium BC the `Chud' people undertook mining of copper, lead, silver and gold in the steppes of central and eastern Kazakhstan. The revival of mining following Russian occupation in east Kazakhstan began by the order of Peter I and 850 ore deposits were open in the Ore Altay of East Kazakhstan in the 18]19th centuries. At the end of the 19th and beginning of the 20th centuries much of this was transferred to foreign companies, principally those of France, Austria, Britain and America until the Soviet period ŽBekhmuhametov, 1964., when these were nationalised.

During the Soviet period a number of very large industrial enterprises were formed, such as Ust-Kamenogorsk Žnow re-named `Oskemen'. for lead]zinc and titanium]magnesium, Leninogorsk and Irtysh for polymetallic extraction, Zyryanovsk for lead, eastern Kazakhstan for copper and Irtysh for chemical]metallurgical processes. During a few decades of intensive development metallurgical industries soon occupied a very wide area.

The long history of metal processing has adversely affected the local environment. The national state of environment data for emissions and ambient environment have shown that east Kazakhstan, especially around Oskemen, is exposed to high levels of a range of pollutants, including heavy metals Že.g. Mnatsakanian, 1992.. Indeed, Oskemen became one of the most important sources of heavy metal pollution in the entire Soviet Union. However, while emissions data were reported Že.g. in the late 1980s atmospheric emissions of cadmium and lead were each over 200 t r year. and extensive contamination of air and local rivers was reported, little research was undertaken on the movement of these contaminants in the environment, particularly through the food chain to the local population.

Here we will describe the distribution of three metals } cadmium, lead and zinc } in plant and animal tissues that lead directly to the human food chain in settlements of differing levels contamination around a major metal processing centre in east Kazakhstan. These data provide the ®rst detailed assessment of the levels of dietary contaminants that may pose a risk for local populations. The research will be complimented by a study of the levels of these metals in human tissues from this region, which will be reported in a subsequent paper.

2. Methods

The area selected for investigation was based around the industrial town of Oskemen, at the centre of the east Kazakhstan region. This study examines two sources of animal feed Žpasture grasses and hay. and three important food animals Žcattle, horses and sheep.. It was important to identify the distribution of metals in surrounding districts which may be subject to different levels of contamination. Six districts were studied Žnone of which had other local industrial pollution sources.: Glubokovskiy; Tavricheskiy; Shemonaihskiy; Ulanskyi; Samarskyi; and Tarbagatayskiy. In order to sample pasture grasses and hay, each district was visited. However, livestock from each of these districts is sent to a common meat-processing plant in Oskemen, where animal tissues were collected. The origin of each was always readily identi®able, although not every district produced all three meat animals.

The districts were chosen following an analysis of wind-rose patterns for Oskemen. These, together with known local metallic deposits allowed for an examination of the dispersion of anthropogenic pollution as well as local natural sources of metals. The districts studied are located either within the metamorphic polymetalic belt Žwith a wide variety of different metal bearing ores. or to the west of the belt, where the geology does not contain such ores. Three of the districts, Glubokovskiy, Tavricheskiy and Shemonaihskiy, were located to the north-west, which receive prevailing winds from Oskemen for 17% of windy days. They were located 30, 45 and 88 km, respectively, from Oskemen and all have an underlying geology which is low in heavy metals. The Ulanskiy district is 50 km to the south-west of Oskemen, receiving prevailing winds from the town on only 8% of windy days. Its underlying geology is high in heavy metals. The Samarskiy and Tarbagatayskiy districts are on the south] south-east 105 and 270 km, respectively, from the regional centre, receiving prevailing winds from Oskemen on approximately 15% of windy days. The underlying geology is low in heavy metals. The metal ore composition of the underlying geology of these districts results in the presence of heavy metals in the overlying soils ŽGrabarov et al., 1968..

Pasture grasses and hay samples were collected within each settlement of each district Žexcept Tarbagatayskiy, which imports hay.. This totaled 27 settlements. Vegetation samples were taken in late spring and early summer during the period of most active vegetation growth. The pasture grass shoots were cut at 1 cm above the root zone to provide standardization of tissue collection. Animal tissues were collected from the meat processing plant in Oskemen. Cattle were supplied by Glubokovskiy, Tavricheskiy, Shemonaihskiy and Ulanskyi districts, totaling 140 animals. Sheep came from Tavricheskiy, Ulanskiy and Tarbagatayskiy districts, totaling 58 animals. Horses came from Tavricheskiy and Samarskiy districts, totaling 30 animals. The total number of animals was, therefore, 228. Animals were collected at the end of the summer and early autumn, allowing the animals to have spent as long a period as possible in the pasture and thus in direct contact with vegetation growing in each district. For each animal, samples of liver, kidneys, lungs, muscles and surface hair were taken. Samples were collected while accompanied by a veterinary hygiene inspector who aided in the collection of internal organs. Samples of hair were collected from the backs and upper ¯anks of the animals. Muscle samples were collected from the upper hind legs of all three animal species.

All samples were placed into labeled plastic bags upon collection. Vegetation samples were kept cool during transport to the laboratory, while animal samples were frozen upon collection to avoid degradation prior to analysis. Samples were ¯own to the laboratory in Almaty to ensure the minimum delay before analysis. Vegetation samples and hair were washed prior to analysis to remove external dust, etc., which might contaminate the results.

Representative samples of vegetation and animal organs were selected for metal analysis. For each analysis 1 g of sample was added to 1 ml of hydrogen peroxide and 3 ml of nitric acid. These samples were digested at 1808C in ¯uoro-plastic vessels in sealed containers which avoided any loss of vapour and, therefore, no reduction in the volume Žand concentration. of the resulting digest. The resulting lead, cadmium and zinc concentrations were analysed by ¯ame atomic absorption spectrophotometry using an ASIN atomic absorption spectrophotometer, following the procedures of Dmitriev and Granovsky Ž1986. and Granovksy Ž1992.. For all analyses control standard solutions were run at the start, during and at the end of sample runs to ensure continued accuracy. For most samples metal concentrations were well within the range of control standard concentrations. However, the accuracy Žand potential contamination. of samples with very low concentrations meant that those with concentrations below a particular threshold were recorded as

Table 1
Contamination of lead, cadmium and zinc in plant tissue from six districts in east Kazakhstan (mg/kg, ± S.D.)

District	Type of sample	Lead	Cadmium	Zinc
Glubokovskiy	Hay	19.36 ± 6.21	0.35 ± 0.12	44.45 ± 7.95
	Pasture grasses	5.85 ± 1.02	0.72 ± 0.9	27.70 ± 2.12
Tavricheskiy	Hay	3.74 ± 0.72	0.24 ± 0.07	30.75 ± 2.27
	Pasture grasses	4.90 ± 0.98	0.35 ± 0.06	22.40 ± 1.96
Shemonaihskiy	Hay	1.83 ± 0.28	0.16 ± 0.02	27.51 ± 2.04
	Pasture grasses	2.80 ± 0.45	0.10 ± 0.02	9.80 ± 1.42
Ulanskiy	Hay	4.22 ± 1.43	0.28 ± 0.08	35.70 ± 1.32
	Pasture grasses	3.50 ± 0.52	0.24 ± 0.04	19.08 ± 2.21
Samarskiy	Hay	1.61 ± 0.06	0.16 ± 0.01	24.78 ± 1.51
	Pasture grasses	2.80 ± 0.31	0.17 ± 0.02	13.10 ± 1.92
Tarbagatayskiy	Hay	1.58 ± 0.01	0.18 ± 0.03	45.22 ± 7.87

'trace' concentrations, given that zero measurements are difficult to demonstrate. Overall, 1230 samples were analysed for each of the three metals.

3. Results

3.1. Animal feed

Analyses showed that the content of lead in the hay from Glubokovskiy is significantly higher than in other settlements. Pasture grass lead concentrations were also higher, but these were not significant (Table 1). In a north-westerly direction from the centre of Oskemen the concentration of contaminants in the plant tissues gradually decreases. For example, lead contamination in hay from the Tavricheskiy district is one-fifth of that of hay from Glubokovskiy. In Shemonaihskiy district it is less than one-tenth of that in Glubokovskiy and half the level of that from the Tavricheskiy district. A similar distribution of accumulation between districts was found for cadmium and zinc.

The Ulanskiy district was located on the windward side, but the high natural metal concentrations in native rocks probably influenced the metal content in the plant tissues. Lead, cadmium and zinc levels here are lower than in the Glubokovskiy district, but higher than in Tavricheskiy and Shemonaihskiy. The lowest metal concentrations were found in Samarskiy and Tarbagatayskiy districts which can be explained by the long distance from the pollution sources and absence of natural deposits of polymetallic ores.

Linear regression was used to assess the association between metal concentrations and the distance to the source of pollution. Only data from Glubokovskiy, Tavricheskiy and Shemonaihskiy districts were used, as they are located on the same main windrose direction and characterised by the same underlying natural ore zone, thus reducing the influence of underlying geology. The results are shown in Table 2 which demonstrate that a significant relationship between pollutant concentration and distance from the main pollution sources.

3.2. Animal tissues

The results of the analysis of metal contamination in animal tissues (Tables 3–5) showed that the highest concentration of lead was contained in surface hair and, from the internal organs, in

Table 2
Coefficients of regression analyses of metal concentrations in forage with distance from pollutant sources

Forage sample	Metal	*r*
Hay	Lead	0.96
	Cadmium	0.97
	Zinc	0.94
Pasture grasses	Lead	0.99
	Cadmium	0.97
	Zinc	0.99

kidneys and liver, but less so in muscle and lungs. The main organ for cadmium accumulation was the kidney, followed by the liver, surface hair, lungs and muscle. Maximal concentrations of zinc were found in surface hair, followed by muscle, liver, kidneys and lungs. Species distinctions were found in metal contamination between the different kinds of livestock animals. The highest metal concentrations were registered in horses, then in cattle, with the lowest in sheep.

There was also an association between metal contamination in cattle organs and distance to pollution sources. Thus, in the Glubokovskiy district, located closest to the centre of Oskemen, the concentration of lead and cadmium in liver, kidneys and lungs and zinc concentration in muscle, liver, kidneys and lungs were higher than in the other areas. Animals from the Tavricheskiy district had a higher lead concentration in liver, kidneys and surface hair and also cadmium and zinc concentration in all organs and surface hair than in the less polluted Shemonaihskiy district. In the Ulanskiy district contamination of lead and zinc was lower in all organs than in Glubokovskiy and cadmium concentration was lower in kidneys only. Signi®cant differences in lead and zinc concentration in cattle organs from the Ulanskiy, Tavricheskiy and Shemonaihskiy districts were not found, although cadmium concentrations in all cattle organs from the Ulanskyi district are signi®cantly higher than the other districts.

It was not possible to perform regression analyses examining a relationship with distance from Oskemen on horse and sheep tissue concentrations, given that samples could not be obtained from all of the necessary districts. However, re-

Table 3
Heavy metal contamination Žmg r kg. in cattle organs[a]

District	Organ	Pb	MAC	Cd	MAC	Zn	MAC
Glubokovskiy	Muscle	0.67 " 0.08	0.5	0.05 " 0.01	0.05	65.59 " 3.47	70
	Liver	1.02 " 0.09	0.6	0.08 " 0.01	0.10	26.94 " 1.45	100
	Kidneys	1.03 " 0.08	1.0	1.06 " 0.12	0.30	20.17 " 0.12	100
	Lungs	0.87 " 0.05	0.6	0.07 " 0.02	0.10	22.68 " 1.98	100
	Surface hair	4.32 " 0.83		0.14 " 0.06		94.99 " 5.37	
Tavricheskiy	Muscle	0.71 " 0.09	0.5	0.08 " 0.01	0.05	49.30 " 8.90	70
	Liver	0.83 " 0.06	0.6	0.06 " 0.01	0.10	26.60 " 0.90	100
	Kidneys	0.84 " 0.09	1.0	0.39 " 0.05	0.30	19.04 " 4.60	100
	Lungs	0.49 " 0.12	0.6	0.02 " 0.002	0.10	15.70 " 5.00	100
	Surface hair	4.69 " 0.40		0.35 " 0.06		147.2 " 4.02	
Shemonaihskiy	Muscle	0.77 " 0.08	0.5	0.02 " 0.003	0.05	48.20 " 6.00	70
	Liver	0.75 " 0.09	0.6	0.05 " 0.02	0.10	25.40 " 1.80	100
	Kidneys	0.75 " 0.12	1.0	0.13 " 0.02	0.30	19.04 " 1.10	100
	Lungs	0.60 " 0.06	0.6	0.05 " 0.005	0.10	16.31 " 0.80	100
	Surface hair	1.77 " 0.32		0.04 " 0.01		43.10 " 6.90	
Ulanskiy	Muscle	0.61 " 0.06	0.5	0.42 " 0.11	0.05	47.2 " 2.60	70
	Liver	0.77 " 0.08	0.6	0.79 " 0.11	0.10	22.80 " 1.43	100
	Kidneys	0.72 " 0.07	1.0	0.71 " 0.14	0.30	19.00 " 1.20	100
	Lungs	0.54 " 0.12	0.6	0.33 " 0.11	0.10	17.00 " 0.90	100
	Surface hair	6.02 " 0.80		0.42 " 0.06		83.9 " 7.50	

[a] Results are compared to the of®cial permitted state maximal allowed concentrations ŽMAC. for those organs.

Table 4
Heavy metal contamination in horse organs and the MAC for those organs Žmg r kg.

District	Organ	Pb	MAC	Cd	MAC	Zn	MAC
Tavricheskiy	Muscle	0.90 " 0.08	0.5	1.88 " 0.33	0.05	64.19 " 8.83	70
	Liver	2.22 " 1.23	0.6	7.54 " 0.54	0.1	37.73 " 3.95	100
	Kidneys	1.27 " 0.14	1.0	127.86 " 34.21	0.3	36.05 " 4.43	100
	Lungs	0.86 " 0.09	0.6	2.36 " 0.43	0.1	18.41 " 2.56	100
	Surface hair	16.56 " 9.71		Traces		112.70 " 6.29	
Samarskiy	Muscle	0.64 " 0.03	0.5	0.32 " 0.02	0.05	51.21 " 3.12	70
	Liver	1.29 " 0.37	0.6	4.57 " 1.25	0.1	63.28 " 4.33	100
	Kidneys	0.84 " 0.07	1.0	22.91 " 5.26	0.3	49.39 " 4.03	100
	Lungs	0.81 " 0.07	0.6	8.09 " 1.86	0.1	42.32 " 2.76	100
	Surface hair	4.35 " 0.91		4.28 " 0.47		142.81 " 8.37	

sults from cattle tissues only revealed three signi®cant relationships of decreasing concentrations with distance, i.e. for lead in liver and kidneys and for cadmium in kidneys.

State standards ŽMaximal Allowed Concentrations } MAC. are set for meat and meat products ŽMinistry of Health, USSR, 1986. and these are compared to the results found in Tables 3]5. Exceedence of the lead MAC was found in all the organs of cattle from the Glubokovskiy district, in the other districts exceedence only occurred in muscle and liver. The mean lead concentration in muscles exceeded the MAC by 1.2]1.5 times, with 46]70% of the samples having concentrations above the MAC. The mean cadmium concentration in cattle exceeded the MAC only for kidneys

Table 5
Heavy metal contamination in sheep organs and the MAC for those organs Žmg r kg.

District	Organ	Pb	MAC	Cd	MAC	Zn	MAC
Ulanskiy	Muscle	1.16 " 0.09	0.5	0.06 " 0.02	0.05	29.10 " 1.7	70
	Liver	1.16 " 0.1	0.6	0.17 " 0.02	0.1	30.58 " 6.2	100
	Kidneys	0.74 " 0.07	1.0	0.22 " 0.05	0.3	17.60 " 1.1	100
	Lungs	0.70 " 0.0	0.6	0.08 " 0.01	0.1	18.10 " 0.9	100
	Surface hair	2.00 " 0.39		0.11 " 0.02		87.50 " 5.6	
Tavricheskiy	Muscle	Traces	0.5	Traces	0.05	24.2 " 2.1	70
	Liver	Traces	0.6	Traces	0.1	32.6 " 2.6	100
	Kidneys	Traces	1.0	0.04 " 0.01	0.3	18.9 " 1.6	100
	Lungs	0.06 " 0.03	0.6	Traces	0.1	19.7 " 1.7	100
	Surface hair	3.54 " 0.36		0.36 " 0.04		80.6 " 5.5	
Tarbagatayskiy	Muscle	0.98 " 0.15	0.5	0.19 " 0.01	0.05	29.0 " 1.3	70
	Liver	0.96 " 0.09	0.6	0.27 " 0.01	0.1	24.0 " 1.9	100
	Kidneys	0.93 " 0.06	1.0	0.27 " 0.01	0.3	16.9 " 1.1	100
	Lungs	0.88 " 0.08	0.6	0.18 " 0.07	0.1	13.5 " 1.0	100
	Surface hair	8.60 " 0.84		0.70 " 0.03		81.5 " 5.3	

from the Glubokovskiy district. There, 87% of the samples were higher than the MAC, while in the Ulanskiy, Tavricheskiy and Shemonaihskiy districts the percentage above the MAC were 58, 51 and 10%, respectively.

The metal concentration in horse organs from the Tavricheskiy and Samarskiy districts showed that the lead and cadmium concentrations from the former district were signi®cantly higher than from the latter. However, the content of both elements in these districts exceeded the MAC. High contamination of cadmium was characteristic of the horse organs: the concentrations exceeded the MAC by 6]37 times in muscle samples and up to 428 times in kidneys ŽTable 4.. It is possible that the high concentration of the metal could be explained by a possible high accumulative ability of horses. However, there were no signi®cant differences in zinc contamination and these did not exceed the MAC.

Sheep organs had a lower metal content than those of cattle and horses ŽTable 5.. For instance, some sheep organs from the Tavricheskiy district had only trace concentrations of lead and cadmium. However, muscle samples from the Ulanskiy and Tarbagatayskiy districts still exceeded the MAC for lead by 2.3 and 2 times, respectively.

4. Conclusions

It is clear from the results that animal feed and animal tissues are often highly contaminated in the Oskemen area. This presents a serious potential risk to the health of local populations. There are no published data for contamination for other regions of Kazakhstan, but some unpublished ŽDurumbytov, personal communication 1999. monitoring indicates that of meat samples across the entire republic no more than 1% have lead concentrations exceeding the MAC and only 5% have cadmium concentrations exceeding the MAC. For vegetables, the ®gures are 0.5 and 1%, respectively, for these metals. This illustrates that the contamination in Oskemen is much higher than for most of the rest of Kazakhstan.

However, contamination was not uniform. Maximal concentrations in some settlements of the Glubokovskiy district exceeded background levels of lead, cadmium and zinc by 18, 6 and 9 times, respectively. For the Tavricheskiy and Ulanskiy districts the respective exceedences were 3, 3.2 and 4 times. Consequently, it is possible to conclude that the distance of the distribution of heavy metals in the direction of predominant winds derived from anthropogenic pollution is not greater than 50 km. Moreover, natural underlying ore conditions also play a signi®cant role in determining metal concentrations.

Variations between the quantities of metals accumulated in different organs and between species are well documented. In both cattle and sheep, kidneys and liver invariable have higher levels of most metals than muscle meat ŽVaessen and Ellen, 1985; Vos et al., 1987, 1988; Alloway et al., 1990; Schwarz et al., 1991; Falandysz, 1991; Jorheim et al., 1991; Niemi et al., 1991; Schulzschroeder, 1991; Falandysz, 1993.. These authors have reported metal concentrations from both eastern and western Europe for animals slaughtered for food Žas in this study.. The concentrations found in east Kazakhstan for cattle and sheep kidneys are similar to the higher concentrations found in the European studies. However, those for muscle meat are often many times higher than these former studies. Given also that these studies do not include horse, the most contaminated of meat, the results demonstrate a signi®cant potential for elevated human exposure to these contaminants in east Kazakhstan.

In order to understand the risks of contaminated meat products for human health it is, therefore, necessary to study the levels of contamination in human tissues from the Oskemen region.

There are two practical options for reducing the levels of exposure to the local population from contaminated meat. The ®rst is to take action against the emission sources themselves. There has been some recent decline in emissions, due largely to economic constraints. For example Durumbytov Žpersonal communication, 1999. indicated that emissions of lead had declined by approximately 10% since 1991 Ž1676 t r year in 1991. and that in 1998 more than 15% of air samples still exceeded the state Maximal Allowed Concentration. However, this means that there are still signi®cant quantities being released and contamination of local soils may remain important for the food pathway for some time. Future changes in economic development and pollution regulation are uncertain.

The second option is to attempt to reduce human intake of contaminated meat. While prohibition of sale Žor even production. from highly contaminated areas is a possibility, this may cause local political dif®culties. As stated above, the meat samples were taken from a single processing factory in Oskemen and thus careful mixing of meat from different sources could result in products with total metal concentrations below the MAC. However, in the current transition economy conditions in Kazakhstan, farmers are relying less on central distribution systems and are more likely to sell their products themselves. This has, therefore, the potential to lead to consumption by individuals of particularly highly contaminated meat within the polluted districts. It is, therefore, important for food hygiene, or veterinary, scientists to establish a monitoring programme to determine the changing Žor ongoing. risks to health from animal food products in Oskemen in order to inform any adopted management strategy.

References

Alloway B, Jackson A, Morgan H. The accumulation of cadmium by vegetables grown on soils contaminated from a variety of sources. Sci Total Environ 1990;91:223]236.

Bekhmuhametov YB. Non-ferrous metallurgy and mining in pre-revolutionary Kazakhstan. Academy of Sciences, Almaty Žin Russian., 1964:373.

Dmitriev MT, Granovsky EI. Spectrochemical methods for determining heavy metals in environmental samples and biological materials. Practical Manual for Laboratory Analysts of Sanitary-Epidemiological Stations. Almaty Žin Russian. 1986:56.

Falandysz J. Manganese, copper, zinc, iron, cadmium, mercury and lead in muscle meat, liver and kidney of poultry, rabbit and sheep slaughtered in the northern part of Poland 1987. Food Addit Contam 1991;8:71]83.

Falandysz J. Some toxic and essential trace metals in cattle from the northern part of Poland. Sci Total Environ 1993;136:177]191.

Grabarov PG, Solodnekova YA, Kvitko BY. Agrochemical characteristics of soils of Kazakstan. Report of the Soils Institute of Kazakhstan. Almaty Žin Russian., 1968:117.

Granovsky EI. Biological monitoring of heavy metals as criteria for assessment of environmental quality. In: Questions of environmental hygiene. Ministry of Health of the Republic of Kazakhstan Žin Russian., 1992:7]15.

Jorheim L, Slorach S, Sundstrom B, Ohlin B. Lead, cadmium, arsenic and mercury in meat, liver and kidneys of Swedish pigs and cattle 1984]88. Food Addit Contam 1991; 8:210]212.

Ministry of Health. Maximal allowed concentrations for heavy metals and arsenic in food raw materials and food products. Sanitary Rules and Norms No. 42-123-4089-86. Ministry of Health of the USSR, Moscow, 1986:11.

Mnatsakanian RA. Environmental legacy of the former soviet republics. University of Edinburgh, Edinburgh, 1992:209.

Niemi A, Venalainen E, Hirvi J, Kappanen E. The lead, cadmium and mercury concentrations in muscle, liver and kidney from Finnish pigs and cattle during 1987]1988. Z Lebensm-Unters Forsh 1991;192:427]429.

Schulzschroeder G. Lead and cadmium contents in meat, liver and kidney samples from lambs and sheep. Fleischwirtschaft 1991;71:1435]1438.

Schwarz T, Busch A, Lenk R. First studies on lead, cadmium and arsenic contents of feed, cattle and food of animal origin coming from different farms in Saxonia. Dtsch Tierarztl Wochenschr 1991;98:369]372.

Vaessen HAMG, Ellen G. Arsenic, cadmium, mercury, lead and selenium in slaughter animals: a survey of ten years of investigation in the Netherlands. Neth J Nutr 1985; 46:286]288.

Vos G, Lammars H, van Delf W. Arsenic, cadmium, lead and mercury in meat, livers and kidneys of cattle slaughtered in the Netherlands during 1980]1985. Food Addit Contam 1987;4:73]88.

Vos G, Lammars H, van Delf W. Arsenic, cadmium, lead and mercury in meat, livers and kidneys of sheep slaughtered in the Netherlands. Z Lebensm-Unters Forsh 1988;187:1]7.